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An Ecological Study of the Cockroach Habitats of Two Garbage Disposal Areas in Knox County, Tennessee

Harry E. Williams
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Harry E. Williams entitled "An Ecological Study of the Cockroach Habitats of Two Garbage Disposal Areas in Knox County, Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

Arthur C. Cole, Major Professor

We have read this thesis and recommend its acceptance:

James M. Liles, Arthur W. Jones

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

March 1, 1963

To the Graduate Council:

I am submitting herewith a thesis written by Harry E. Williams entitled "An Ecological Study of the Cockroach Habitats of Two Garbage Disposal A eas in Knox County, Tennessee". I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology.

Arthur C. Cole
Major Professor

We have read this thesis and recommend its acceptance:

James M. Lilea

Arthur W. Jones

Accepted for the Council:

Hilton A. Smith
Dean of the Graduate School

AN ECOLOGICAL STUDY OF THE COCKROACH HABITATS OF TWO GARBAGE DISPOSAL AREAS IN KNOX COUNTY, TENNESSEE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

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by

Harry E. Williams

March 1963

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PART I

INTRODUCTION

I. STATEMENT OF THE PROBLEM

This study was made to determine the adaptations to a new environment and the ecological niches in the community that are occupied by cockroaches in two garbage disposal dump areas. The community of this study is the entire area of two garbage disposal dumps. This research is a comprehensive study of the garbage disposal community, including an analysis of its components (physical and biotic), dynamics and seasonal aspects.

Two garbage disposal dump areas were studied. One area is used by Knox County and is under the direction of the County Health Department. The other area is used by the City of Knoxville and is under the supervision of the City of Knoxville, Tenn.

Roth (1960) states that very few exclusively ecological studies of insects have included cockroaches.

II. DESCRIPTION OF SPECIES STUDIED

The three species of cockroaches of primary interest in this study were those which have become house dwellers and are considered to be household pests of great importance. These are Blatta germanica (Linnaeus), 1767; Blatta orientalis (Linnaeus), 1758 and Periplaneta americana (Linnaeus), 1758.

Individuals of these three species are constantly being transported to the disposal areas in the many items of waste material collected daily by the garbage trucks.

Blatta germanica (Linnaeus), 1767. "German Cockroach."

Blatchley (1920) described this species as dull brownish-yellow, the females often darker; all the limbs much paler than the body; disc of pronotum with two dark brown, longitudinal stripes separated by a yellowish one; antennae dark brown, exceeding slightly the tips of the closed tegmina. Tegmina and wings of male extending to end of the abdomen, those of the female slightly longer. Body of male longer and narrower than that of female; middle of sixth abdominal segment with two deep, rounded fossae separated by a narrow ridge on basal portion and deeply concave behind; stylus very minute, the left one the larger, small, rounded decurved. Length of body, male 10.5-11.4 mm., female 11-12.8mm.; of pronotum, male 2.4-2.8 mm., female 3-3.3 mm.; of tegmina, male 9.7-10.2 mm., female 10.8-11.9 mm.; width of pronotum, male 3.1-3.7 mm., female 3.8-4.2 mm.

The German cockroach ranges throughout the United States and the greater part of Canada, being most abundant in the central states. In addition to the common name already given, it is known as the "Water bug" and Burr (1893) states that in Russia it is called the Prussian Roach, while in Germany it is known as the Russian Roach. Piers (1918) says that the local name in Novia Scotia is the "Yankee

settler."

In Indiana and the eastern United States it is best known as the "Croton bug," so called because it made its appearance in New York City in numbers about the time the Croton Aqueduct was completed. It is a native of central Europe, but like the Oriental roach, has become cosmopolitan. In Europe it is found in woods as well as in houses.

In America, the German cockroach seldom, if ever, occurs in numbers in rural areas, but is one of the worst insect pests with which the inhabitants of the larger cities of the United States have to deal. It is the most fecund of all roaches and the seasons of mating and hatching of the young are perhaps more irregular than those of any other species. Adult forms are evidently to be found at all seasons of the year, as they have been taken in Knoxville in December, April and October. This cockroach is not so much a lover of filthy surroundings as is the Oriental roach and hence frequents more often than that species the dwellings of relatively prosperous class of people. It thrives in warm, moist places and is especially abundant and destructive in buildings which are heated by steam. This species is a great nuisance in kitchens, pantries, bakeries, warehouses, manufacturing plants and ships. According to Essig (1942), this species is abundant in garbage dumps and organic debris of all kinds.

and organic debris of all kinds.

Metcalf and Flint (1939) state that the females of this species carry their egg capsules protruding from the abdomen for about two weeks until the eggs are nearly ready to hatch. There are commonly twenty-five to thirty eggs in each capsule, sometimes as many as forty-six, and a female produces from one to seven or more capsules during her lifetime. The nymphs pass through seven molts in six to eight weeks and the total life span is two to five months, with two or three generations a year in the average house.

Blatta orientalis (Linnaeus), 1758. "Oriental Cockroach."

According to Blatchley (1920), the male is nearly uniform shining dark chestnut-brown; pronotum and tegmina often slightly paler; legs and under surface dark chestnut-brown. Pronotum suboval; widest behind the middle, its angles and sides broadly rounded, disc with a broad impression each side on basal third. The tegmina of the male cover about two-thirds of the abdomen and are strongly overlapping. In the female the tegmina are represented by small oval, widely separated pads. Supra-anal plate twice as wide as long, carinate above at middle, its apex truncate. Cerci short, flat or feebly concave above, widest at middle, their tips acute. Subgenital plate transverse, convex near apex,

the latter rounded. Styles slender, cylindrical, straight, equal in length to the distance between their sockets and the base of subgenital plate. The female is larger and stouter than male, about one inch long, head wider, the interocular space greater. Nearly uniform, shining blackish-brown, the legs slightly paler. Pronotum much larger, widest near base, the latter truncate. Supra-anal plate subtriangular, strongly keeled, its apex feebly concave. Subgenital plate compressed so as to form a carina or ridge on its underside and divided so as to be bivalved.

The Oriental cockroach is found in all the larger towns and cities and is one of the most annoying and disagreeable insects with which certain classes of their inhabitants have to contend. It seldom occurs in houses in thinly settled localities and never goes beneath the bark of logs and stumps. It is a cosmopolitan species which has spread throughout the tropical and temperate zones and is known in all parts of this country and most of Canada. Hebard (1917) states that in Philadelphia it appears in swarms during the month of May, coincident with the arrival of the shad in the Delaware River and is, therefore, locally known as the "Shad Roach."

As its name indicates, the Oriental roach is a native of Asia, but has been carried from one country to another by shipping. It thrives in filth and darkness and hence in

the holds of vessels, the cellars and basements of tenement houses and in all damp, dirty places where it swarms by the thousands, undoubtedly doing much good as a scavenger, but infinitely more harm because of its omnivorous and insatiable appetite.

This species is most prevalent in damp basements and along sewer lines and is considered the filthiest of all roaches. Essig (1942) states it is often abundant in the huts of savages and in ships, dwelling houses, hotels, slaughter houses, garbage dumps and similar locations affording food and protection. Like most other members of the family, it feeds mainly at night. The Oriental roach is probably the most carnivorous of all the Blattidae, though like most others, it is fond of starchy food. It is known to feed upon meat, cheese, woolen clothes and even old leather.

This species is notably gregarious in habit, the individuals living together in colonies, the small ones being allowed by the larger ones to sit on them, run over them and nestle beneath them without a show of intolerance.

The life cycle is about thirteen months. The female produces an average of fourteen or fifteen capsules, averaging twelve to sixteen eggs each.

Periplaneta americana (Linnaeus), 1758. "American Cockroach."

Blatchley (1920) stated that the male's head is chestnut-brown; tegmina shining reddish-brown; pronotum broadly margined on sides and base and narrowly in front with yellow, this enclosing a large, bilobed brown spot which is usually sharply defined, though sometimes much suffused; legs and under surface pale brownish-yellow, middle of abdomen darker. Pronotum sub-elliptical, widest at middle, narrowed in front, its angles all broadly rounded; discal oblique impressions broad, feeble. Supra-anal plate of male with apical half membranous. Cerci fifteen jointed, very long (6-7 mm.) and strongly tapering. The female is stouter, head and pronotum broader, the latter with discal impressions less obvious; tegmina and wings shorter. Supra-anal plate weakly keeled above, not membranous, subgenital plate as in other Blattinae. The length of this species is one and one-half inches or more.

The American cockroach is, as its specific name indicates, a native of tropical and sub-tropical America; but like Blatta orientalis, it has spread to the four corners of the earth. It is usually confined to the basement and first floor of a building and seems to be much more discriminating in its choice of an abiding place than does the closely allied Oriental cockroach.

Marlatt (1902) says that the domesticity of the American cockroach resulted from ages of association with the aborigines.

This species now has become thoroughly cosmopolitan and is unquestionably the most injurious and annoying of the species occurring on vessels.

Essig (1942) reports this species is indigenous to Mexico and Central America, whence it has been carried by commerce throughout the world. The species often flies and is common in the streets and open fields by night and may also be seen during the day.

The female drops the egg capsule or glues it in a sheltered place by secretions from her mouth, and may produce a capsule once a week until fifteen to ninety capsules, averaging about fourteen to sixteen eggs, have been formed. The nymphs hatch in thirty-five to one hundred days and require ten to sixteen months and thirteen molts before reaching the adult stage. According to Metcalf and Flint (1939), the total life span is sometimes as long as two and one-half years. The rate of growth of it and other species depends largely on the food and temperature conditions and under unfavorable circumstances the nymphal stage is much prolonged. The abundance of cockroaches is, therefore, apparently not accounted for so much by their rapidity of multiplication as by their unusual ability to preserve themselves from ordinary means of destruction and by the scarcity of natural enemies. This species often becomes abundant in city dumps and is most common in basements, restaurants, bakeries, packing houses and grocery stores.

PART II

METHODS

I. FIELD EQUIPMENT AND PROCEDURES

Field Equipment

The field equipment used in this study included the following: an ordinary aerial insect net with a hoop one ft. in diameter and a handle one yd. long, a small entrenching tool (for securing soil and litter samples), a mattock (for digging into the debris), a hatchet, a small forked digging tool, colorimetric soil testing kit (to test hydrogen ion concentration of soil), thermometer, camera, film, insect killing bottles (chloroform and cyanide), assorted specimen containers (such as vials and pill boxes), forceps, compass, flashlight and spiral notebook.

The special equipment used consisted of baited traps (constructed from wide-mouth jars and screen wire) Peterson (1949), funnel shaped collecting stands (to collect from litter samples), mouse traps, cyanide dust gun for fumigating the crevices and a rubberised tarpaulin for special collecting of small mammals. A special infra-red light was devised for use on night collecting trips.

Frequency and Time of Field Trips

The frequency of the field trips varied from twice daily in the hottest weather to once in fifteen days during

the period of coldest weather. The usual trips were made at intervals of one week. They were most frequent during the fall, spring and summer months and when detailed studies were being conducted. The four areas of the garbage dump were visited on each trip; however, the visits were concentrated on specific areas for detailed study. The area of new dumping would be studied extensively on one trip, with general work over the other areas, and on other trips the undisturbed areas would be given detailed study, with general observations of the other areas.

Variations in weather and in the activities of the dump operation induced variations in the frequency of visits and in the studies made during the visits. The field trips were generally made between 8:00 A.M. and 5:30 P.M. However, some trips were made before and after these times, including trips made at twilight and during darkness, both in the early morning and later evening. The visits were made on clear days as a rule; however, trips were made during rain and on cloudy or windy days to study the environment in the extreme condition. In winter the trips were generally made on the warmer days, but some were made to the area during the time that killing frosts and light snows prevailed.

Study Area Visitations and Data Recorded

The study area was divided into four sections, as described in Part III. On each visit to the area, detailed analysis was made of a small part of each section by probing

and digging into the debris. The entire study area was observed generally, the activity of the arthropods noted and special studies made of the debris where unusual activity or abundance of forms occurred.

In general, studies were made of the debris and materials in various stages of decay, ranging from the first to the dry, dark last stage. The kind and number of operations were variable on each visit due to the seasons, the weather, the state of decay of the materials, the location and immediate surroundings, the disturbance by the garbage disposal workmen and the activity and abundance of arthropods.

Observations were made and records kept on the condition of the dump during the field trips, noting the area where the new dumpings were being added, the undisturbed areas, the areas which had the most noticeable odors, those where dead rats were decaying on the surface, and those where the arthropod activity was unusual or noticeably abundant. Photographs were frequently taken to supplement the written records.

The insects of principal interest in this study, the cockroaches, avoid the bright light and remain in the dark cracks and crevices so that probing and digging in the debris was necessary to collect and observe them. A small area in each section of the study area was selected for specific study on each trip. These areas included those that had been undisturbed for a number of days to several weeks, as well as

those that were being used for dumping on the day of the field trip. The areas selected for study were chosen because of the moisture, the nature and abundance of food materials, the abundance of the materials that could be used for abode by the insects, the unusual activity of the surface arthropods, and in some cases, the odors which prevailed.

The probing and digging were difficult because of the nature of the material and the disturbance of the arthropod forms was unavoidable. Collecting was also hampered or impeded because of the numerous cracks and crevices affording escape to the rapidly moving forms and the use of an aspirator was not applicable to the filth of the area. After the specific study of the small areas in each section was completed, a general survey was also taken. The general survey consisted of collecting the flying forms with an ordinary aerial insect net and also more digging and probing in the general area in all four sections of the dump, as well as in the immediate surrounding area. Further details of the observing and recording will be discussed in other sections of this study.

Frequently the air above the dump area was saturated with Diptera and other flying forms and many insects were observed resting and feeding or ovipositing on the surface debris. On each field trip when the flying forms were numerous an ordinary aerial insect net was used for collecting by sweeping the air in all sections and in the immediate

surrounding area.

The specimens of various arthropods which could not be identified in the field were often collected with bare fingers, forceps, traps, fumigation and an ordinary insect net. Large scale collection of most groups of insects was generally avoided, because an undue disturbance of the community was not desirable.

In order to determine kinds and to estimate abundance of the numerous species of small arthropods which could not be identified in the field, samples of litter and soil were secured, placed in paper bags and brought into the laboratory for examination. These samples were taken when there was unusual activity or abundance of small arthropods observed during the probing and digging in the debris. The samples were not taken in a regular square or quadrat, because of the nature of the debris; however, each time about one pint of the material was collected. The condition of the material ranged from the first to the last stages of decay and was in some cases animal matter and in others vegetable matter, or sometimes, a mixture of both. The samples were taken more frequently in the spring, summer and fall; however, some were collected in the winter months. Samples were taken at depths from one to four feet below the surface of the debris.

To determine the temperature of the study area, a

number of multiple readings were taken of the debris temperatures and the air temperatures. In determining the temperature of the debris, a thermometer was placed in the debris eighteen inches below the surface in the winter, spring, summer and fall seasons. The bulb of the thermometer was in contact with the debris which consisted of a variety of materials with a wide capacity for the conduction of heat. Corresponding surface temperatures were taken by means of a well shaded laboratory thermometer, placed in contact with the debris, or within two inches of the surface material. Air temperatures were taken by means of a well shaded laboratory thermometer placed six inches above the ground. All readings were made in an area with a radius of three feet and the temperature recorded when the thermometer had been in position for a period of five minutes. A total of fifty such multiple readings were made between 8:00 A.M. and 4:30 P.M. on various days. Several readings were made during each season of the year.

II. LABORATORY PROCEDURES

The collected specimens were pinned or preserved in alcohol or other preservative and labeled according to date, section number and method of collection.

Specimens of flies taken with the net were sorted and individuals that could be identified were counted. All specimens of the common, easily identified species were not

preserved because of the huge numbers in which they occurred. Specimens which could not be identified were preserved and sent to specialists for identification.

The soil and litter samples were placed on a screen in the top of a Berlese funnel under a strong light and left for twenty-four hours. The small specimens were collected in a container of preservative below the funnel. The large specimens were picked out of the samples with forceps as the samples were deposited on the screen. The vast number of arthropods occurring in these samples precluded retaining all the specimens. Representative specimens of the various forms were collected and estimates made of the abundance of the remainder.

III. ESTIMATES OF ABUNDANCE

Determination of the abundance of species was one of the most difficult problems encountered in this study. Some species were present in numbers too large to permit accurate counts. Certain individuals of species which were present in numbers small enough to count were frequently hidden under debris and overlooked. Many species could not be distinguished in the field; therefore, estimates of abundances were based on the number of individuals captured.

The abundance of the species varied considerably in all sections of the study area, due to the many ecological

factors and preference of individual species. Some species were represented by a rare or scarce number of individuals at one point, but were abundant a short distance away.

The necessity for different procedures in capturing various forms of insects precluded the establishment of a set standard which could be applied in estimating abundances of all forms.

Varied species of insects were difficult to collect due to variations in alertness, rapidity of flight, escape into crevices when disturbed and position on or in the debris. The individual insects in the aggregation were more alert at times due to species present, meteorological conditions and other factors. Wind, temperature, rainfall and the condition of the surface debris seemed to be significant factors in influencing the behavior, activities and habitat preferences of the various forms.

One of the most difficult phases of the study was a determination of the successional pattern of the various arthropod forms in the debris. The difficulty was intensified by the addition of fresh material adjacent to or on top of putrefying or dried material. Considerable migration of the forms due to various ecological factor changes produced an inconclusive pattern of the various forms from the older layers of the area to the new fresh deposits of material.

Another of the most difficult phases of the work in this area was the establishment of an accurate and complete identification of all the various forms comprising the fauna of the area. The variety of forms was too numerous to permit more than a general survey.

The Five Term Scale of Abundance.

In the field the actual number of insects observed were recorded, if possible. A five term scale similar to that used by Cantrell (1943) was employed when insects were present in such abundance as to preclude an accurate count. The terms of the scale are: rare, scarce, medium numbers, common and abundant. This scale was used to estimate both the number of individuals of a particular species and the number of families present.

PART III

LOCATION

I. CLIMATE AND WEATHER OF THE LOCALITY

Knoxville is located in a broad valley between the Great Smoky Mountains, which lie southeast of the city, and the Cumberland Mountains, which lie northwest of the city. In winter the Cumberland Mountains lessen the force of cold air, which often travels far south of the latitude of Knoxville, over the plains areas to the west of the mountains. In summer the mountains lower the temperatures of hot winds, which are common to the plains of the west. Sudden, great temperature changes occur infrequently, due again mainly to the retarding effect of the mountains. The diurnal variations between night and daytime temperatures average about 20° F. (U. S. Dept. Comm., 1952). The first and last killing frosts of the year average November 2 and April 2 respectively (U. S. Dept. Comm., 1960).

Official weather records were obtained from the Knoxville Municipal Airport, located twelve miles from the study area. According to these records, the first killing frost of the fall of 1961 occurred on October 27, with a low of 32° F. Snow during the period of study never exceeded 21.5 inches and most of it fell in December 1961, and January and March 1962. Normal monthly temperatures and precipita-

tion and deviations from normal during the period of study are shown in Figure 1. Figure 2 shows that temperatures were normal for every month except October and December 1961 and January, March, April, June and July 1962.

II. THE STUDY AREAS

The two study areas are located approximately fourteen miles from each other, with one area northeast of Knoxville, Tennessee and the other southwest of Knoxville. The county dump area is adjacent to Badgett Rd. in the west section of Knox County. The city dump area is located off the Asheville Highway in the east section of Knox County.

The hilly terrain and the vegetation are typical of the great Appalachian Valley, which centers at Knoxville. The underlying rocks are principally limestone and Tellico sandstone. The soils are comprised chiefly of various loams.

The study areas are used for the disposal of garbage collected six days a week from homes, stores, restaurants and other institutions. There is a wide variety of items in the dump that are used as shelter and hiding places by the arthropods and small mammals. Included in these are boxes, cans and bottles of all shapes and sizes made from many types of material. The substances that may be used as food by the arthropods are in a varied state of decay at the time they are deposited on the dump. The migration of the arthropods to the more attractive areas, with subsequent

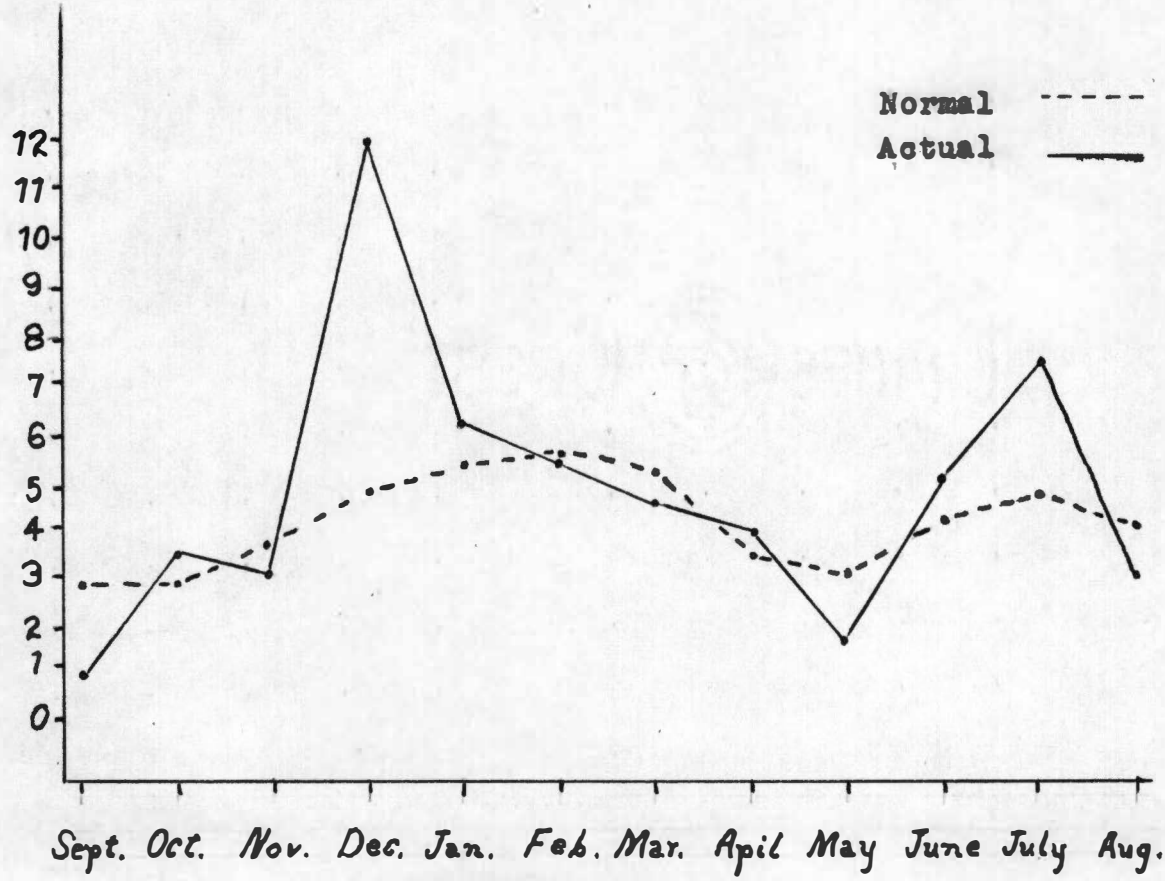


FIGURE 1

PRECIPITATION IN INCHES,
NORMAL AND ACTUAL,
1961 AND 1962

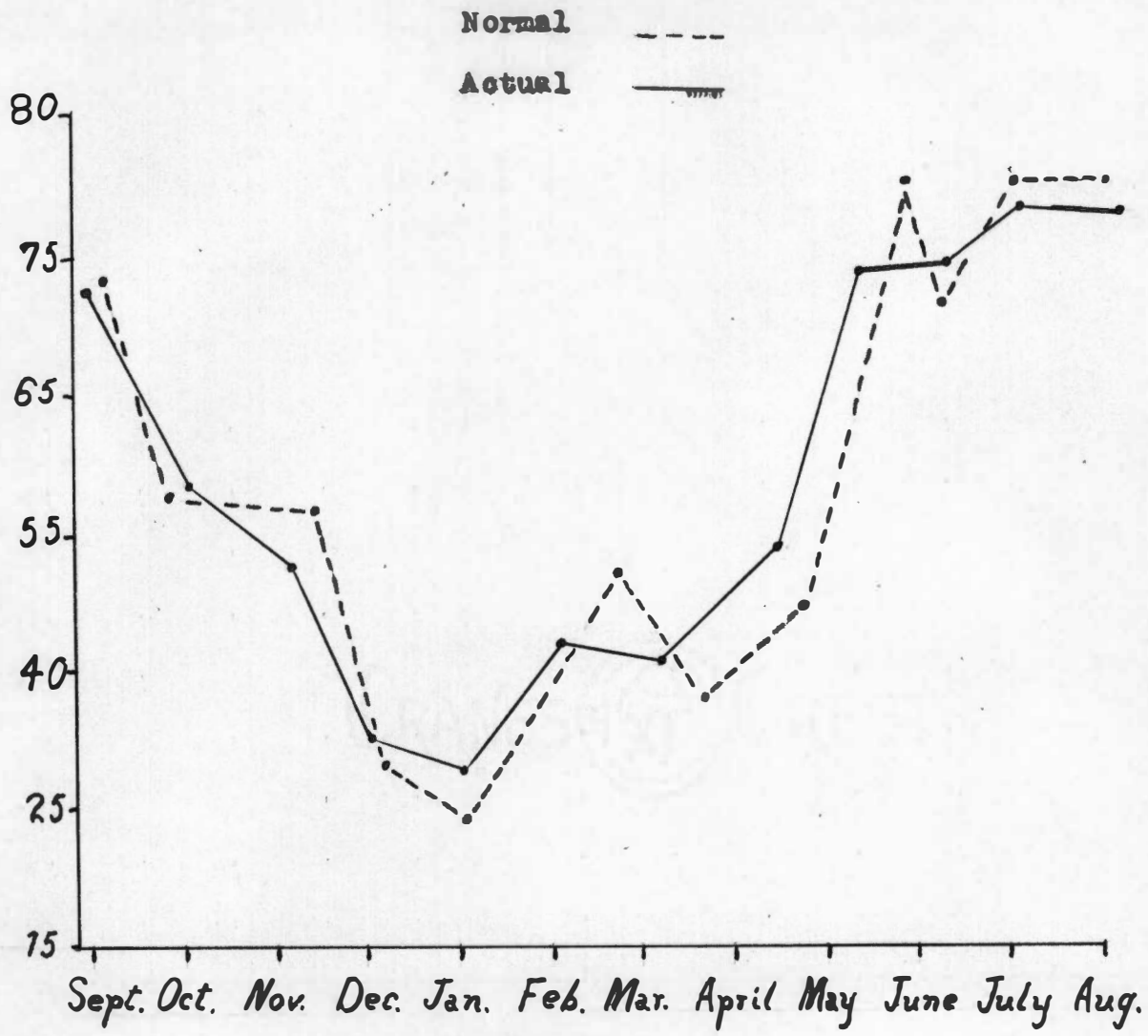


FIGURE 2

TEMPERATURE DEGREES FAHRENHEIT,
NORMAL AND ACTUAL,
1961 AND 1962

alteration of the normal sequence, would be very difficult to ascertain with accuracy. However, this was attempted by a process of marking the insects and releasing them and trapping them later.

The study areas are free of domestic animals (except stray dogs, cats and some pigs belonging to the caretakers). Many small mammals are present, the most common being rats which are present in large numbers.

The study areas are described in detail below.

The County Dump Area

The hilly terrain is very typical of this area and the dump area is centered in a large ravine which is well protected by the surrounding hills from the cold winds of winter. The area is in the direct sunlight with only the southeastern part of Section 2 receiving a noticeable amount of shade in the morning. Excellent drainage is afforded the area by the ravine on the southern margin of the dump area; however, a large amount of water is retained by the absorbent materials and containers in the area. The dump area is very porous because of the many items such as paper, boxes, cans, bottles, tires, boards, bales of paper and clothing that greatly reduce the density of the fill material and offer excellent shelter to arthropod life in the area. The area has been in use as a garbage dump for seven years, under the direct supervision of the Knox County Health Department.

Garbage is dumped on the area into piles from the trucks that collect it at various points throughout the county. The piles of garbage are then spread and packed down by a bulldozer and they remain uncovered until the area has been completely filled. The area is then covered with a four inch layer of fill dirt and packed again. The garbage remains uncovered for several days and at times a week or even longer before it is covered over with the layer of fill dirt. During this time the garbage is spread out by a bulldozer to facilitate drying of the material and to permit inspection for burning or smouldering material. The absorbent materials become saturated with water during the seasons when the rainfall is sufficient to prevent the operation of the bulldozer for the moving of the fill dirt. See Figure 3.

The City Garbage Disposal Area

The area has been in use as a garbage disposal dump for two years. The dump area is centered in a large ravine which is surrounded by a hilly terrain typical of the locality. It receives direct sunlight throughout the entire day, except for a section of Area II that is noticeably shaded by the surrounding hills in the afternoon. The area is being filled in with materials similiar to those described for the county area and the density of the fill is about the same. The materials are handled here in the same manner as in the county dump area, except that the fill dirt is not applied

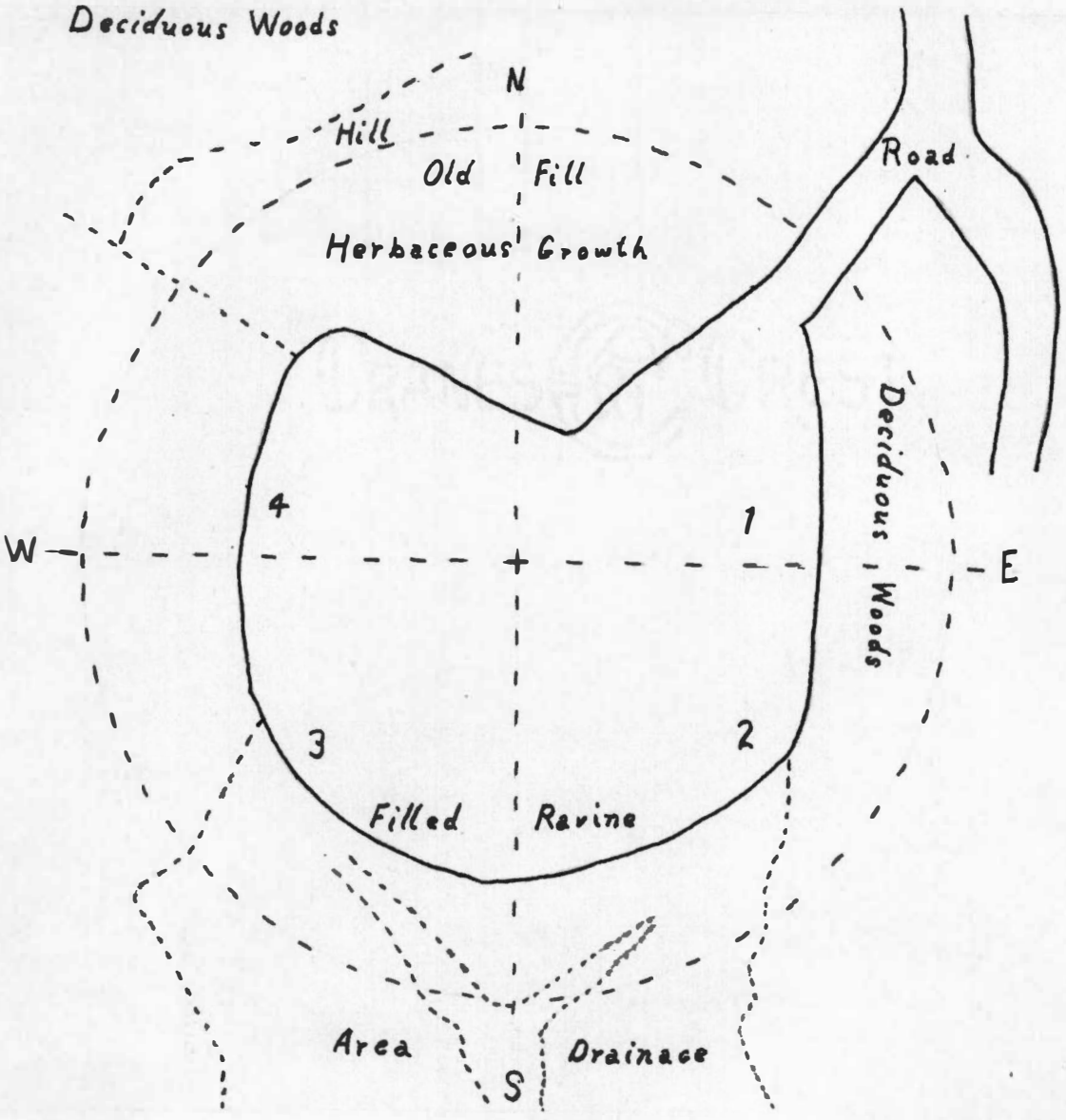


FIGURE 3

COUNTY DUMP STUDY AREA

as regularly or as often as it is on the county dump area. Drainage is provided by a ravine on the northeastern margin of the area. However, most of the water is retained by the porous material and containers. The porous nature of the fill material offers shelter and hiding places for arthropods and the many containers, such as cans, bottles, tires and buckets hold a good supply of water for them. See Figure 4.

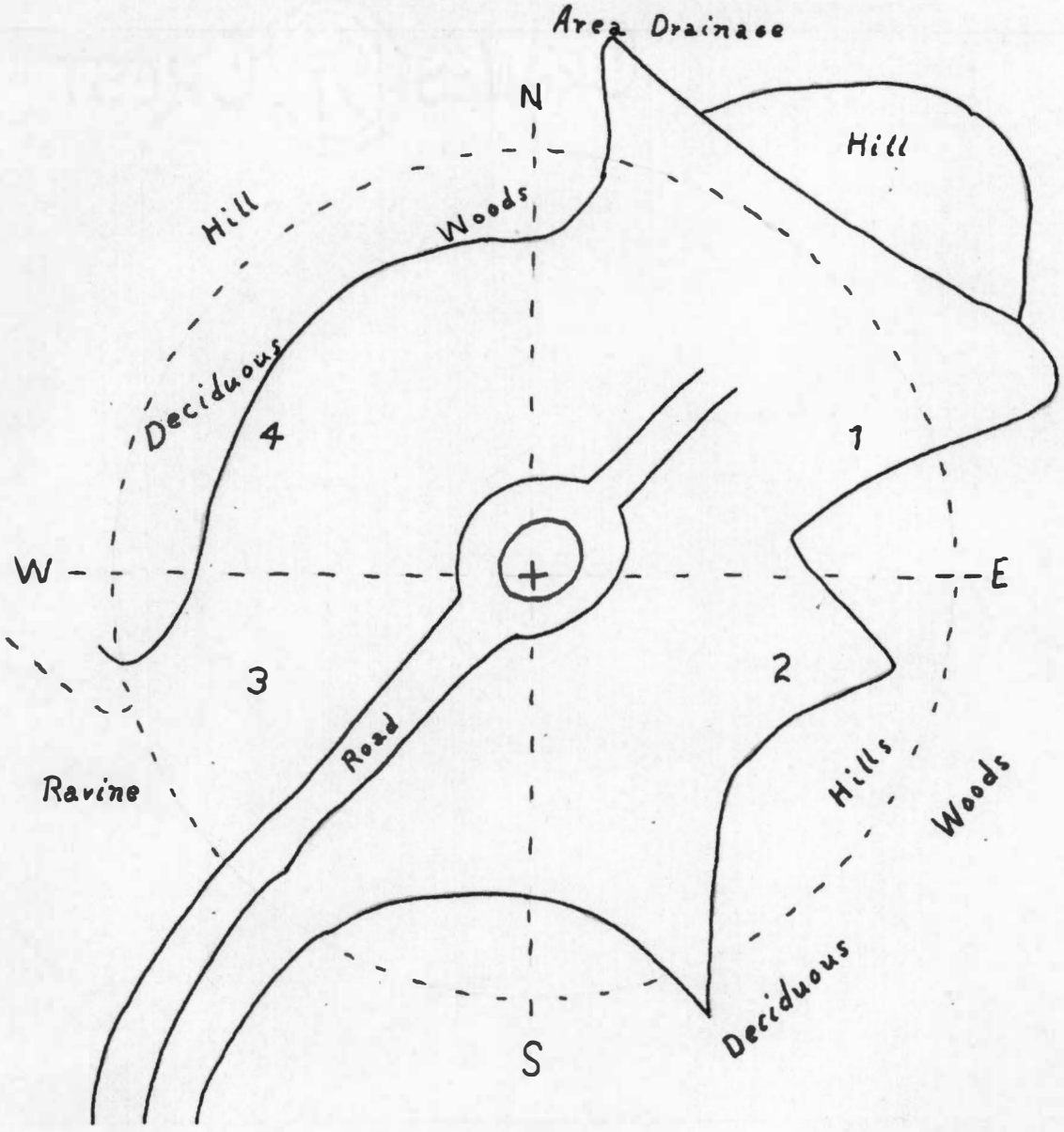


FIGURE 4

CITY DUMP STUDY AREA

PART IV

RESULTS

I. ECOLOGICAL NICHES

Blatta germanica exhibited a definite preference for the surface debris of the area. It is found on and under the surface debris in all seasons. The colder winter weather forces its migration from part of the surface area where there is a considerable drop in the temperature. There are many warm niches which are dominated by this species in all phases of its development during the fall and winter months. There is a decline in the activity in the winter when extreme climatic changes occur. This species was observed in the surface debris at all times during the day.

This species definitely exhibited a wider range of tolerance to higher temperatures, lower humidity levels and light ray gradations. It followed a definite arrhythmic behavior in the dump communities.

Periplaneta americana is well established in the debris just below the surface in the areas which have been covered with fill dirt. This area is occupied during all seasons of the year and there is considerable activity by this species during the winter. Nymphs and females bearing egg capsules are abundant in the heated niches of this area.

Blatta orientalis remains well below the surface of the debris in all seasons, during the daytime. It is commonly found at a depth of one to two feet below the surface in the more recently filled areas of the dump. However, it is well established in the lower levels of the older part of the dump.

It is interesting to note that Supella supellectilium was not found in the garbage areas while this study was being conducted, even though it is well established in Knoxville buildings.

See Plate I.

II. COMPARISON WITH OTHER OBSERVATIONS

Walden (1922) observed a heavy infestation of Blatta germanica in a dump in New Haven, Conn. At one edge of the dump this species was found in numbers under loose bark and in cavities in trees. Several specimens of Periplaneta americana were also found in the trees. The cockroaches were active at night and swarmed on nearby houses and street trees as far as a city block from the dump.

Hansens (1950) observed a dump in New Jersey that was sprayed with fuel oil and set on fire in an attempt to control Blatta germanica. This treatment resulted in flights up to four blocks from the dump, even though this species does not usually fly.

PLATE I

Illustration of Habitats

a. *Blatta germanica*

b. *Blatta germanica*

c. *Blatta germanica*

d. *Blatta germanica*, *Periplaneta americana*

e. *Periplaneta americana*

f. *Periplaneta americana*, *Blatta orientalis*

g. *Periplaneta americana*, *Blatta orientalis*

h. *Blatta orientalis*

a.

b.

c.

d.

e.

f.

g.

h.

Roth (1957) reported that Dr. Theodore Olson witnessed a mass migration of Blatta germanica from a city dump to a sewer plant in Austin, Minn.

Shuyler (1956) also observed that the German cockroach sometimes occurs in large numbers outside buildings.

Haines and Palmer (1955) observed that Blatta germanica outnumbered all other species of cockroaches inside homes, but Periplaneta americana was most prevalent in sewers. Population pressure, it was concluded, may be a factor inducing migration from sewer systems into homes.

Allee (1949) states that activity occurring both day and night under normal conditions is said to be arrhythmic with respect to the diel cycle. He also states it seems certain that the activity pattern is usually, if not always, modifiable by the environment.

Roth (1957) states it has been conclusively demonstrated that cockroaches do migrate from sewers into homes. Probably the extent of migration is much greater than recovery of marked insects would indicate. Although there are specific differences in their behavior, many cockroaches show relatively little discrimination in their choice of food and habitat. This does not imply that all species are found in exactly similar locations, but only that all domesticated species may be found in both clean and dirty habitats.

Shuyler (1956) stated that Blatta orientalis is frequently found outdoors around homes during the summer months and can become exceptionally numerous in garbage and trash dumps. He also reported a marked increase in the frequency of occurrence and duration of infestations outdoors in the temperate north central area, that the yards of whole blocks of homes have been described as "alive" with Oriental cockroaches on warm summer nights.

Cloudsley (1953) reported a composite diurnal locomotory rhythm has been established in adult, male Oriental cockroaches. He found that the major peak of activity occurred shortly after nightfall.

PART V

DISCUSSION

The entire surface of the study areas is being changed constantly by the workmen in handling the garbage materials. New materials that are being added to the area daily will provide food and shelter for large populations of arthropods. Many of the arthropods that are living in the debris near the surface are covered over and buried much deeper as the piles of garbage are spread over the area by the bulldozer. The arthropods that survive the crushing and packing of the debris by the bulldozer and the trucks, as the garbage materials and fill dirt are piled on and spread over the dump, find tons of food and thousands of hiding places available as they migrate toward the surface. The disturbance by the workmen is the largest single unnatural change occurring in the area. The method used in handling the material and adding to the entire area in layers is such that an area of the dump will remain undisturbed from days to weeks once the the layer of garbage has been deposited. After the fill dirt layer is put down over the garbage layer, the arthropods are not disturbed again except by natural forces. Each layer of the dump will provide food, water, shelter and protection for a large population.

The food supply of the arthropods in the study area is augmented daily and there are types to furnish the diet of a wide variety of arthropods. The items of food are a composite of all the food materials used by man, as well as hundreds of other items that may be used by other forms of life. Items of food found in the area fall into all of the categories of food classification, including the carbohydrates, fats and proteins, of both plant and animal origin. The food materials have been prepared in all of the ways known to man and are in all of the various stages of decay and preservation. A complete listing of the various food items would be too long to accomplish here. Some of the items are worthy of special mention, however. These include small dead mammals in various stages of decay, many kinds of meats, fish, grains, flour, meal, bread, vegetables, paper, glue, pasteboard, wood, fur, cloth (wool and cotton), beer, various parts of many animals from slaughter houses, fats from vegetable and animal origin and fruit.

Some of the food material is in a mass so that the heat is retained, thus forming extensive culture media for the rearing of bacteria and arthropods. Many of the food items are in small pieces that dry out or cool sufficiently to be preserved for later use by the arthropods.

Allee (1949) states that adjustments to the environment are made by both general and particular modifications

of structure and function. Inevitably, the survival of the species depends upon its association with foods sufficient to meet these requirements. In the overwhelming majority of organisms, this is accomplished by each species becoming a member of a food-feeder nexus. These natural, cooperative groups are relatively self-sufficient and the component species populations are spatially integrated and stratified.

Water is available in large amounts for the insects and other arthropods in the many containers such as cans, bottles, jars and buckets that collect the surface and rain water during the rains of the seasons and hold this water for future use by the organisms. Many materials in the area are very absorbent and hold large amounts of the rain water. Water is available on many of the items in the dump, having condensed out of the air and formed droplets on the surfaces of these items. Sufficient water is available to supply the needs of large populations of insects and other arthropods. The density of the garbage is very low, due to the large amount of air spaces caused by the cans, boxes, cartons, boards, paper, metal articles and the decay of much of the material. The numerous air spaces and the large amount of water in cans and other items, together with the heat absorption and conduction by many of the materials, cause evaporation of the water, forming a very humid atmosphere for the insects. Also, a considerable amount of water is re-

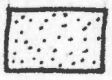
leased from the decaying material as it breaks down.

The garbage contains thousands of items of many shapes and sizes, which are made from many different materials. The layers of garbage are very porous, due to the many items such as cans, boxes, barrels, old furniture and appliances. Also, the breaking down or decay of large amounts of material leaves more air space or runways for the arthropods. The nature of the material is such that large populations of arthropods are supplied with shelter in each layer of the dump. When the layer of garbage is covered with fill dirt, it holds heat and moisture, thus giving additional protection to the arthropods and helping to stabilize the factors of the environment. See Figure 5.

The study area has a wide range of temperature variations, influenced by the climatic conditions and the liberation or absorption of heat by the materials in the area. The action of these two forces results in a favorable temperature range in a large part of the area throughout the entire year. The temperature range is greatest during the extreme cold weather and less variable during the warmer months. See Figure 6.

According to Gunn (1935) a sharp upper limit of preferred temperature was established for the three cockroach species of this study, but the lower limit is not so sharply defined and will require more work. Blatta germanica is the only species that will enter and remain in temperatures that

Debris 

Fill dirt 

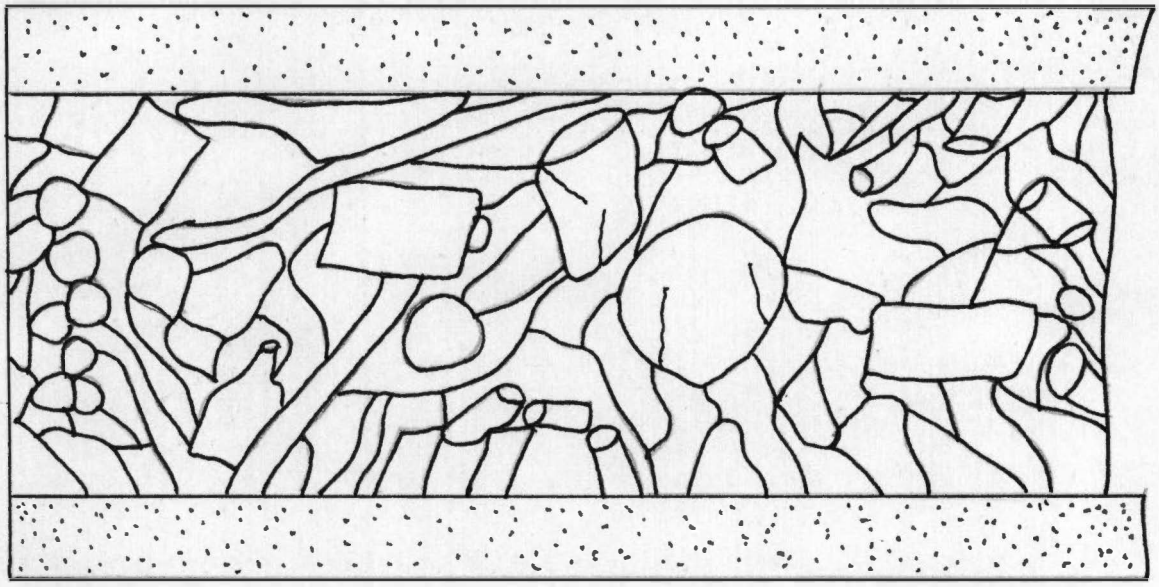


FIGURE 5

SHELTER AND PROTECTION

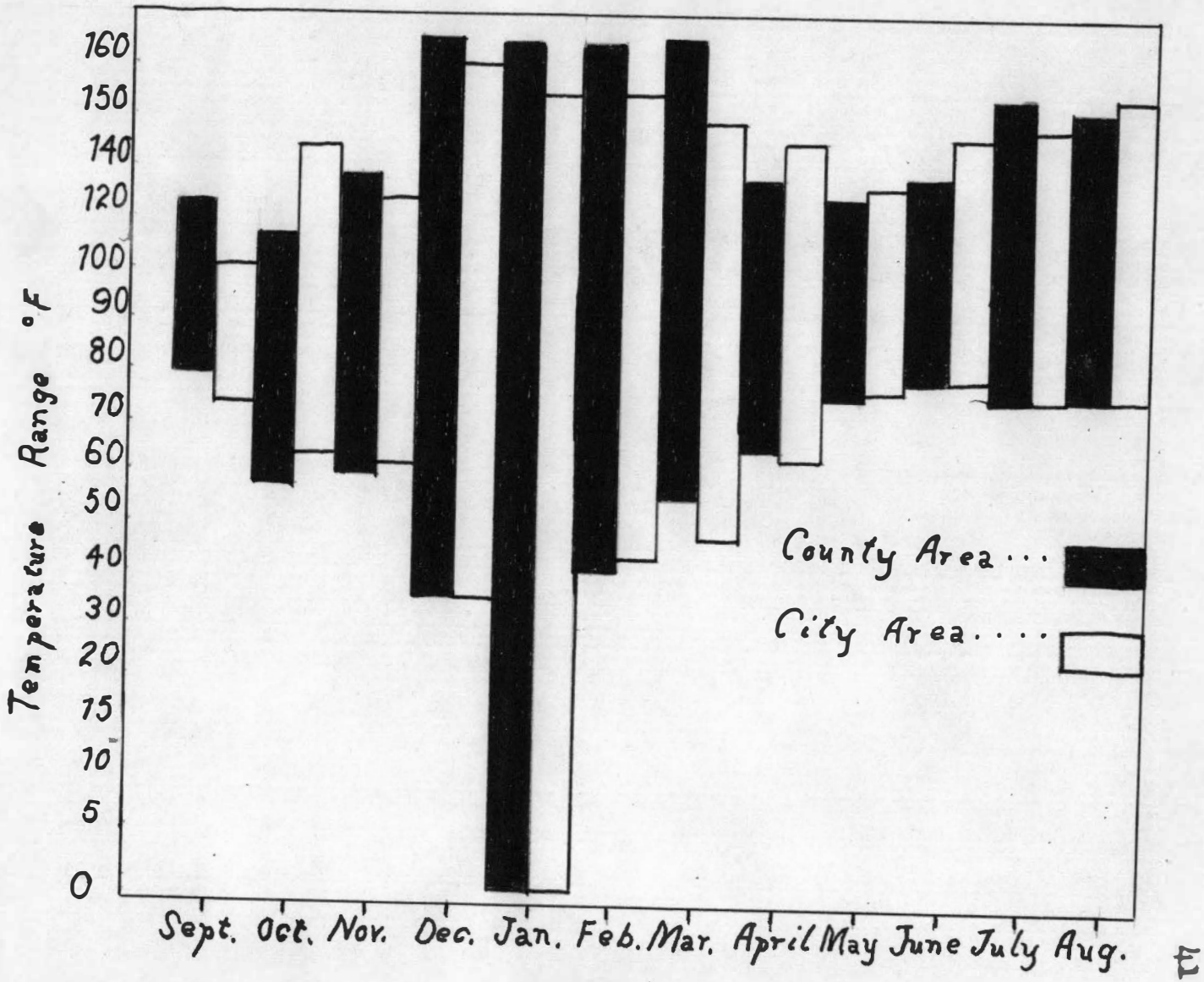


FIGURE 6

TEMPERATURES OF STUDY AREAS

result in rapid dessication. In all three species, at 30° C. in dry air the insect loses about 6 mg. of water by evaporation for every 1 mg. of oxygen consumed. The smallest species, Blatta germanica, with the thinnest cuticle, loses least rapidly per unit of surface area. The upper limit of preferred temperature of Blatta germanica and Periplaneta americana is 33° C., while for Blatta orientalis it is 29° C. The lower limit is not so sharply defined and further work is required before it can be regarded as significant.

Gunn (1936) established the thermal death point for Blatta germanica at 35 - 39° C. in moist air and 33 - 39° C. in dry air. No explanation has been found for the wide variation in this species. The threshhold fatal temperature for Periplaneta americana was found to be 37 - 39° C. and for Blatta orientalis 37 - 38° C.

The humidity of the study areas is generally favorable for those insects that prefer a humid habitat, but there are also dry spots in the debris.

Gunn (1938) stated that in a diffusion gradient of humidity at uniform temperature, Blatta orientalis showed a tendency to spend more time in the drier region. Individuals of other species appear to be indifferent to the stimulus of air humidity. In a temperature gradient, those individuals which react to humidity have a slight, but significant, higher preferred temperature in somewhat moist

air than they have in dry air.

Allee (1946) stated the hydrogen ion concentration is no more important than many other environmental conditions and is usually less significant than water in various forms, light, heat, soil and other conditions. A series of fifty pH readings was taken in each of the two study areas during July 1962. The readings were made over the entire areas and results were very similar, with no significant differences being observed between the two study areas. See Table I.

The constant physical forces acting upon the garbage disposal areas create a favorable environment for the propagation of many arthropod species throughout the entire year. The extreme condition resulting from the action of one force is minimized by the counter action of another force. The decay of the material in the area is impeded or accelerated by the variations of the temperature and moisture in the immediate vicinity. During the winter, the temperature of an immediate area is regulated by the counter actions of the general climatic conditions and the heat liberated by the decomposing material. Excessive heat from the material may be quenched by rain.

The data of this study are not presented as a complete discussion of the entire arthropod fauna of the garbage disposal areas, as the fauna is too complex to treat fully.

TABLE I

HYDROGEN ION CONCENTRATION

COUNTY DUMP AREA					CITY DUMP AREA				
7.2	6.0	7.5	7.5	7.5	7.4	7.0	6.5	5.6	7.5
7.2	6.5	5.4	5.0	7.4	5.4	4.3	4.5	5.0	6.5
7.4	7.5	6.5	8.0	7.8	5.0	6.5	5.0	5.8	5.5
7.8	7.7	5.6	7.3	7.6	5.0	6.5	5.2	7.2	5.6
7.2	7.3	7.4	7.8	7.5	7.5	7.4	7.0	7.2	7.5
7.4	7.2	7.4	5.6	7.2	7.8	7.4	7.5	7.5	7.6
5.0	5.5	5.0	6.5	5.0	7.2	7.6	7.2	5.6	7.8
7.2	4.5	7.5	7.5	5.5	7.8	7.8	7.8	8.2	6.5
7.2	6.6	7.2	6.8	7.2	6.8	6.8	5.0	5.4	6.5
6.8	5.0	5.8	5.0	5.0	7.2	7.5	7.5	7.6	6.4

The major classes abundant in the warm, moist surface debris are Annelida, Crustacea, Arachnida, Diplopoda, Chilopoda, Mammalia and Insecta. The predominant group of the area is the class Insecta, and is represented by eleven orders which are well established in or visit the area frequently. The order Diptera is the dominating group of the area and many species of this group are present in all seasons. Representatives of the orders Hymenoptera, Hemiptera, Lepidoptera and Odonata are abundant in the spring and summer. The orders Coleoptera, Collembola, Thysanura, Isoptera and Dermaptera are abundant in the surface and lower layers of the debris in all seasons. The order Orthoptera is represented by three families which are well established in the debris and other families which are occasional visitors. The established families are Blattidae, Gryllidae, and Tettigoniidae. Some species of the family Locustidae are frequent visitors to the area.

The majority of the species of the area are not dependent upon the garbage materials for survival. However, the life histories of a number of the Diptera, Coleoptera, Orthoptera, Thysanura and Collembola indicate they are dependent upon the garbage materials for survival.

PART VI

SUMMARY

This study was made in order to determine the adaptations to a new environment and the ecological niches that are occupied by cockroaches in a garbage disposal area. The three species of cockroaches used in this study are: Blatta germanica, Blatta orientalis and Periplaneta americana. All three species are considered to be household pests of great importance.

The field study was conducted at the Knox County and the City of Knoxville garbage disposal areas in Knox County, Tennessee. The study was started in September 1961 and completed in September 1962.

The weather and climatic conditions were quite favorable for arthropod populations of the area. There was one extreme change which occurred on the 9th of January 1962, when a low of 2° F. was accompanied by eleven inches of snow in the area. Freezing temperatures prevailed for several weeks following the extreme drop in temperature. Blatta germanica, which had been abundant in the surface of the debris prior to January 9, was not observed again until April 15, 1962 and was rare on that date. This species shows a definite preference for the warm, moist surface, and exhibits a definite arrhythmic behavior.

Blatta orientalis definitely prefers the darker, damp, moist layer and is absent from the surface debris except during the night. This species is commonly found with or in the vicinity of the American cockroach.

Periplaneta americana definitely exhibits a preference for a more protected or deeper layer of the debris, but in the hot summer months is commonly found in the surface of the debris with the German cockroach.

Supella supellectilium was not observed in the areas during this study.

The observations made in this study agree with those of other authors, with the exception of Catesby. *Periplaneta americana* does not lie torpid all winter as stated by Catesby, but was observed to be very active and reproducing in all seasons.

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